CLAIMS

1. A reformer reactor for producing hydrogen gas from hydrocarbons comprising:

(a) a first zone;

(b) a second zone adjacent the first zone; and,

(c) a flow path for directing flow of a reaction stream in diverging directions from the first zone into the second zone, the flow of the reaction stream continuing in the same general diverging directions through the second zone.

2. The reactor of Claim 1, including at least a third zone adjacent the second zone, the flow path continuing a flow of the reaction stream into and through the third zone in the same general directions as the reaction stream flowed into and through the second zone.

3. The reactor of Claim 2, including a fourth zone adjacent the third zone, the flow path continuing a flow of the reaction stream into and through the fourth zone in the same general directions as the reaction stream flowed into and through the second zone.

4. The reactor of Claim 1 wherein the first and second zones are generally spherical and the flow directions are radially away from the first zone.

5. The reactor of Claim 1 wherein the first and second zones are generally hemispherical and the flow directions are radially away from a spherical portion of the hemispherical first zone.

6. The reactor of Claim 1 wherein the first and second zones are generally cylindrical and the flow directions are radially away from the first zone.

7. The reactor of Claim 1 wherein the first and second zones are generally cylindrical and the flow directions are axially away from the first zone.

8. The reactor of Claim 2 wherein the first, second, and third zones are generally spherical and the flow directions are radially away from the first zone.

9. The reactor of Claim 2 wherein the first, second, and third zones are generally hemispherical and the flow directions are radially away from a spherical portion of the hemispherical first zone.

10. The reactor of Claim 2 wherein the first, second, and third zones are generally cylindrical and the flow directions are radially away from the first zone.

11. The reactor of Claim 2 wherein the first, second, and third zones are generally cylindrical and the flow directions are axially away from the first zone.

12. The reactor of Claim 3 wherein the first, second, third, and fourth zones are generally cylindrical and the flow directions are radially away from the first zone.

13. The reactor of Claim 1 including a first partition separating the first and second zones, the first partition having a plurality of spaced openings to permit the flow of the reaction stream therethrough.

14. The reactor of Claim 2 including a first partition separating the first and second zones, and a second partition separating the second and third zones, both the first and second partitions having a plurality of spaced openings to permit the flow of the reaction stream respectively therethrough.

15. The reactor of Claim 6 including a first partition separating the first and second zones, the partition having a plurality of spaced openings to permit flow of the reaction stream therethrough.

16. The reactor of Claim 10 including a first partition separating the first and second zones, and a second partition separating the second and third zones, both the first and second partitions having a plurality of spaced openings to permit the flow of the reaction stream therethrough.

17. The reactor of Claim 13 including:

(a) a partial oxidation reaction vessel being located within the first zone, the vessel having an opening for emission of reactants into the first zone; and,

(b) the number, size, and spacing of the partition openings being selected to control the flow rate and uniformity of the reaction stream from the first zone and into the second zone.

18. The reactor of Claim 13 including:

(a) a partial oxidation reaction vessel being located within the first zone, the vessel having an opening for emission of reactants into the first zone; and,

(b) the first partition being constructed of material composition, thickness, and finish to assist in controlling heat transfer between the reaction vessel and the second zone.

19. The reactor of Claim 1, wherein:

(a) at the first zone the reaction stream including a partially-oxidized hydrocarbon and hydrogen gas; and,

(b) the second zone containing a catalyst.

20. The reactor of Claim 2, wherein:

(a) at the first zone the reaction stream including a partially-oxidized hydrocarbon and hydrogen gas; and,

(b) at least one of the second or third zone containing a catalyst.

21. The reactor of Claim 3, wherein:

(a) at the first zone the reaction stream including a partially-oxidized hydrocarbon and hydrogen gas; and,

(b) at least one of the second, third, or fourth zones containing a catalyst.

22. The reactor of Claim 6, wherein:

(a) at the first zone the reaction stream including a partially-oxidized hydrocarbon and hydrogen gas; and,

(b) the second zone containing a catalyst.

23. The reactor of Claim 10, wherein:

(a) at the first zone the reaction stream including a partially-oxidized hydrocarbon and hydrogen gas; and,

(b) at least one of the second, third, or fourth zones containing a catalyst.

24. The reactor of Claim 6 wherein the axial ends of each of the zones have a thermally-insulating member.

25. The reactor of Claim 10 wherein axial ends of each of the zones have a thermally-insulating member.

26. The reactor of Claim 22 wherein axial ends of each of the zones have a thermally-insulating member.

27. The reactor of Claim 23 wherein axial ends of each of the zones have a thermally-insulating member.

28. The reactor of Claim 10, wherein:

(a) at the first zone the reaction stream including a partially-oxidized hydrocarbon and hydrogen gas; and,

(b) at least one of the second or third zone containing a catalyst.

29. The reactor of Claim 12, wherein:

(a) at the first zone the reaction stream including a partially-oxidized hydrocarbon and hydrogen gas; and,

(b) at least one of the second, third, or fourth zones contain a catalyst.

30. The reactor of Claim 19 wherein the second zone includes a catalyst suitable for catalyzing a steam reforming reaction in the reaction stream.

31. The reactor of Claim 20 wherein the second zone includes a suitable catalyst for catalyzing a steam reforming reaction in the reaction stream, and the third zone contains a suitable catalyst for catalyzing a high-temperature shift reaction in the reaction stream.

32. The reactor of Claim 21 wherein the second zone containing a suitable catalyst for catalyzing a steam reforming reaction in the reaction stream, and the third zone containing a suitable catalyst for catalyzing a high-temperature shift reaction in the reaction stream, and the fourth zone including a suitable catalyst for catalyzing a low-temperature shift reaction in the reaction stream.

33. The reactor of Claim 22 wherein the second zone includes a suitable catalyst for catalyzing a steam reforming reaction in the reaction stream.

34. The reactor of Claim 28 wherein the second zone containing a suitable catalyst for catalyzing a steam reforming reaction in the reaction stream, and the third zone containing a suitable catalyst for catalyzing a high-temperature shift reaction in the reaction stream.

35. The reactor of Claim 29 wherein the second zone containing a suitable catalyst for catalyzing a steam reforming reaction in the reaction stream, the third zone containing a suitable catalyst for catalyzing a high-temperature shift reaction in the reaction stream, and the fourth zone containing a suitable catalyst for catalyzing a low-temperature shift reaction in the reaction stream.

36. The reactor of Claim 13 wherein the first partition is a screen mesh.

37. The reactor of Claim 14 wherein the partitions are a screen mesh.

38. The reactor of Claim 17 wherein the first partition is a screen mesh.

39. The reactor of Claim 18 wherein the partition is a screen mesh.

40. The reactor of Claim 1 including a partial oxidation reaction vessel being located within the first zone, the vessel having an opening for emission of partially-oxidized hydrocarbons into the first zone.

41. The reactor of Claim 19 including a partial oxidation reaction vessel being located within the first zone, the vessel having an opening for emission of partially-oxidized hydrocarbons into the first zone.

42. The reactor of Claim 2, including a reactant feed stream for providing reactants into the reaction stream and means for heat exchange with the reactant feed stream prior to entry of the reactants into the first zone, the means being disposed in at least one of the second or third zones so as to utilize heat from the reaction stream flowing therethrough to preheat the feed stream.

43. The reactor of Claim 3, including a reactant feed stream for providing reactants into the reaction stream and means for heat exchange with the reactant feed stream prior to entry of the reactants into the first zone, the means being disposed in at least one of the second, third, and fourth zones so as to utilize heat from the reactant stream flowing therethrough to preheat the feed stream.

44. The reactor of Claim 20, including a reactant feed stream for providing reactants into the reaction stream and means for heat exchange with the reactant feed stream prior to entry of the reactants into the first

zone, the means being disposed in direct contact with a catalyst in at least one of the second or third zones so as to utilize heat from the reactant stream flowing therethrough and the heat from the catalyst to preheat the feed stream.

45. The reactor of Claim 21, including a reactant feed stream for providing reactants into the reaction stream and means for heat exchange with the reactant feed stream prior to entry of the reactants into the first zone, the means being disposed in the catalyst for direct contact therewith in at least one of the second, third, and fourth zones so as to utilize heat from the reactant stream flowing therethrough and the heat of the catalyst to preheat the feed stream.

46. The reactor of Claim 30 wherein the means for heat exchange with a reactant feed stream also including means for regulating the heat exchange so that a desired thermal gradient can be maintained in the catalyst of the third zone and the reaction stream temperature across the zone wherein the means for heat exchange is disposed.

47. The reactor of Claim 31 wherein the means for heat exchange with a reactant feed stream also having means for regulating the heat exchange so that a desired thermal gradient can be maintained in the catalyst of the third zone and the reaction stream temperature across the zone wherein the means for heat exchange is disposed.

48. The reactor of Claim 32 wherein the means for heat exchange with a reactant feed stream also having

means for regulating the heat exchange so that a desired thermal gradient can be maintained in the catalyst of the third zone and the reaction stream temperature across the zone wherein the means for heat exchange is disposed.

49. The reactor of Claim 1 including:

(a) a means for flowing oxygen to the first zone;

(b) a means for flowing a fuel to be oxidized to the first zone; and,

(c) a means for cooperating the means for flowing oxygen and the means for flowing fuel such that the flow of fuel assists the flow of oxygen.

50. The reactor of Claim 6 including:

(a) a means for flowing oxygen to the first zone;

(b) a means for flowing a fuel to be oxidized to the first zone; and,

(c) a means for cooperating the means for flowing oxygen and the means for flowing fuel such that the flow of fuel assists the flow of oxygen.

51. The reactor of Claim 10 including:

(a) a means for flowing oxygen to the first zone;

(b) a means for flowing a fuel to be oxidized to the first zone; and,

(c) a means for cooperating the means for flowing oxygen and the means for flowing fuel such that the flow of fuel assists the flow of oxygen.

52. The reactor of Claim 49 wherein the means for cooperating including joining the fuel flow into the oxygen flow downstream of a source of the oxygen and

flowing the fuel at a higher velocity than a velocity of the oxygen upstream of joining the fuel flow.

53. The reactor of Claim 49 wherein the fuel is a hydrocarbon which is a gas at standard temperature and pressures and is delivered to the fuel flow from a pressurized container.

54. The reactor of Claim 49 wherein the means for flowing oxygen includes a first tube, the means for flowing fuel includes a second tube, and the means for cooperating including a union of the first and second tubes such that a spray of fuel can issue from the second tube inside the first oxygen-carrying tube.

55. A reformer reactor for producing hydrogen-rich gas comprising:

(a) a vessel having a first zone for containing a reaction stream with reactants, a collection space for collecting product gas, at least one intermediate zone interposed between the first zone and the collection space; and,

(b) a means for directing a heated reactant stream from the first zone to the collection space primarily in the direction coinciding with the direction of a substantial portion of the overall heat flux out of the vessel.

56. The reformer reactor of Claim 55 having three zones interposed between the first zone and the collection space.

57. The reformer reactor of Claim 56 wherein the second zone containing a suitable catalyst for catalyzing a steam reforming reaction in a reaction stream, the third zone containing a suitable catalyst for catalyzing a high-temperature shift reaction in a reaction stream, and the fourth zone containing a suitable catalyst for catalyzing a low-temperature shift reaction in a reaction stream.

58. The reformer reactor of Claim 55 wherein the all of the zones are arranged as nested coaxial cylinders and the vessel including sufficient thermal insulation at its axial ends such that heat flux and accordingly the reactant flow, is primarily radially outward from the first zone to the collection zone.

59. The reformer reactor of Claim 57 wherein all of the zones are arranged as nested coaxial cylinders and the vessel including sufficient thermal insulation at axial ends of the nested cylinders such that the heat flux, and accordingly the reaction stream flow, is primarily radially outward from the first zone to the collection space.

60. The reformer reactor of Claim 55 including a partial oxidation reactor located in the first zone for issuing a partially-oxidized hydrocarbon reactant mixture to the first zone.

61. The reformer reactor of Claim 59 including a partial oxidation reactor located in the first zone for issuing a partially-oxidized hydrocarbon reactant mixture to the first zone.

62. The reformer reactor of Claim 57 including a partial oxidation reactor located in the first zone for issuing a partially oxidized hydrocarbon reactant mixture to the first zone.

63. A reformer reactor for producing a hydrogen-rich gas comprising:

(a) a first zone for containing reactants;

(b) at least one other zone within which the first zone is nested; and,

(c) a boundary between each zone, the boundary being permeable to a reaction stream so as to permit flow thereof from the first zone to and through each subsequent zone through the respective boundaries therebetween.

64. The reformer reactor of Claim 63 having three nested zones around the first zone.

65. The reformer reactor of Claim 64 wherein the second zone containing a suitable catalyst for catalyzing a steam reforming reaction in the reaction stream, the third zone containing a suitable catalyst for catalyzing a high-temperature shift reaction in the reaction stream, and the fourth zone containing a suitable catalyst for catalyzing a low-temperature shift reaction in the reaction stream.

66. The reformer reactor of Claim 63 wherein the first zone is a cylinder and the three subsequent zones are tubular cylinders all nested coaxially and a closure is provided at axial ends of the cylindrical zones, such that the reaction stream flow is primarily radially outward from the first zone to and through the third zone.

67. The reformer reactor of Claim 64 wherein the first zone is a cylinder and the three subsequent zones are tubular cylinders all nested coaxially and a closure is provided at axial ends of the cylindrical zones, such that the reaction stream flow is primarily radially outward from the first zone to and through the third zone.

68. The reformer reactor of Claim 63 including a partial oxidation reactor located in the first zone for issuing a partially-oxidized hydrocarbon reactant mixture to the first zone.

69. The reformer reactor of Claim 65 including a partial oxidation reactor located in the first zone for issuing a partially-oxidized hydrocarbon reactant mixture to the first zone.

70. The reformer reactor of Claim 67 including a partial oxidation reactor located in the first zone for issuing a partially oxidized hydrocarbon reactant mixture to the first zone.